

GOES-R Algorithm Working Group (AWG) Level-2 Product Validation Activities

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AWG Team Leads and all members of the GOES-R AWG teams

NOAA/NESDIS, Center for Satellite Applications and Research

January 10, 2013



OUTLINE

- **GOES-R series instruments, data and products**
- **Importance of calibration and validation (Cal/Val) to the GOES-R Program**
- **Ongoing Pre-launch activities**
- **Planning for Post-launch Cal/Val activities**
- **Summary**



Instrument Overview

GOES-R supports NOAA mission to provide forecasts and warnings for the United States, its territories, and adjacent waters for the protection of life and property and the enhancement of the national economy.

GOES-R is the next generation of GOES satellites that will provide a major improvement in quality, quantity, and timeliness of data collected.

Earth Pointing

In-Situ

Sun Pointing

ITT EXELIS

LOCKHEED MARTIN

Assurance Technology Corporation

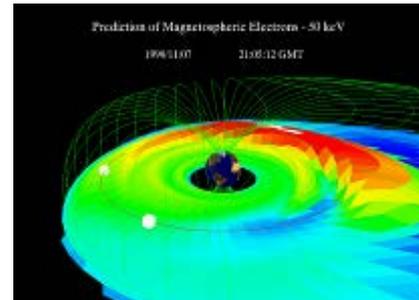
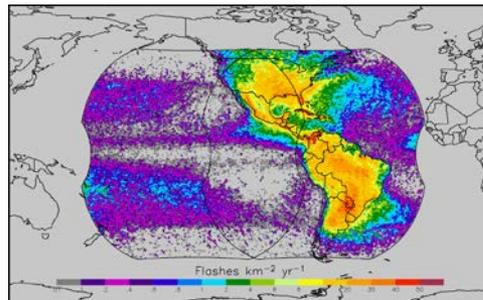
LOCKHEED MARTIN
CLASP

Visual & IR Imagery

Lightning Mapping

Space Weather Monitoring

Solar Imaging



- **Advanced Baseline Imager (ABI)**

- **Geostationary Lightning Mapper (GLM)**

- **Space Environment in-Situ Sensor Suite (SEISS)**
- **Magnetometer**

- **Solar Ultra-Violet Imager (SUVI)**
- **Extreme UV/X-Ray Irradiance Sensors (EXIS)**

New and improved capabilities for:

- increased lead times for severe weather warnings
- better storm tracking capabilities
- solar, space weather, and climate analyses
- advanced products for aviation, transportation, commerce

**Launch
Readiness
Oct. 2015**



GOES-R Data and Products



Baseline Products

Advanced Baseline Imager (ABI)

- Aerosol Detection (Including Smoke and Dust)
- Aerosol Optical Depth (AOD)
- Clear Sky Masks
- Cloud and Moisture Imagery
- Cloud Optical Depth
- Cloud Particle Size Distribution
- Cloud Top Height
- Cloud Top Phase
- Cloud Top Pressure
- Cloud Top Temperature
- Derived Motion Winds
- Derived Stability Indices
- Downward Shortwave Radiation: Surface
- Fire/Hot Spot Characterization
- Hurricane Intensity Estimation
- Land Surface Temperature (Skin)
- Legacy Vertical Moisture Profile
- Legacy Vertical Temperature Profile
- Radiances
- Rainfall Rate/QPE
- Reflected Shortwave Radiation: TOA
- Sea Surface Temperature (Skin)
- Snow Cover
- Total Precipitable Water
- Volcanic Ash: Detection and Height

Geostationary Lightning Mapper (GLM)

- Lightning Detection: Events, Groups & Flashes

Space Environment In-Situ Suite (SEISS)

- Energetic Heavy Ions
- Magnetospheric Electrons & Protons: Low Energy
- Magnetospheric Electrons: Med & High Energy
- Magnetospheric Protons: Med & High Energy
- Solar and Galactic Protons

Magnetometer (MAG)

- Geomagnetic Field

Extreme Ultraviolet and X-ray Irradiance Suite (EXIS)

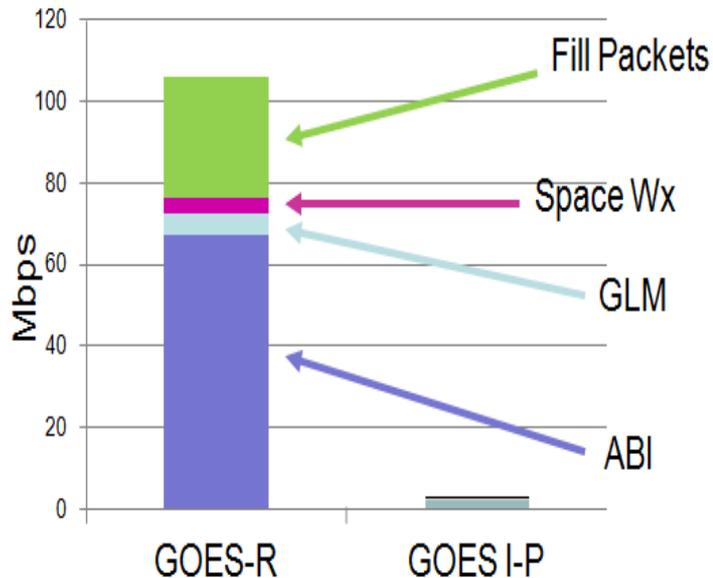
- Solar Flux: EUV
- Solar Flux: X-ray Irradiance

Solar Ultraviolet Imager (SUVI)

- Solar EUV Imagery

Level-2 products
(Environmental parameters)

GOES-R Raw Data Throughput



ABI provides 3x spectral, 4x coverage, and 5x temporal resolution of current imager

GOES-R product requirements drive instrument performance requirements, which often are the same as, or more strict than, heritage GOES.

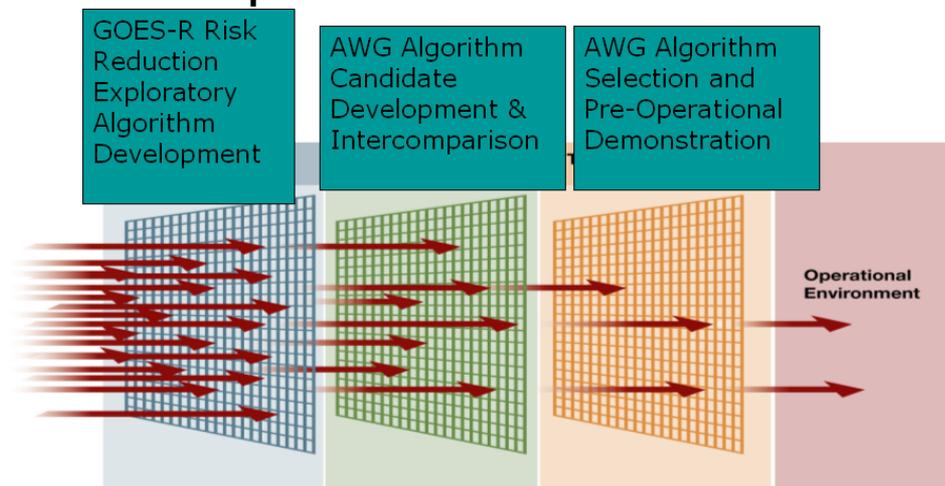
• Mission:

- To select, develop, test, validate, and demonstrate Level-2 algorithms meet the GOES-R requirements and provide them to the GOES-R Ground Segment.
- Provide sustained life cycle validation and Level-2 product enhancements

• End-to-End Capabilities

- Instrument Trade Studies
- **Proxy Dataset Development**
- **Algorithm Development and Testing**
- **Product Demonstration Systems**
- **Development of Cal/Val Tools**
- Integrated Cal/Val Enterprise System
- Radiance and **Product Validation**
- Algorithm and application improvements
- **User Readiness** and Education

Algorithm Research to Operation Process

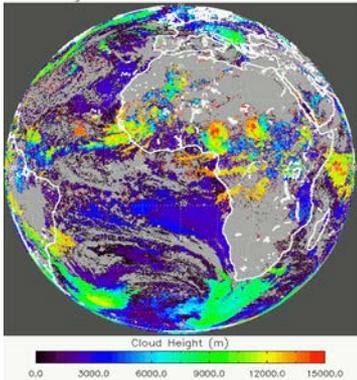




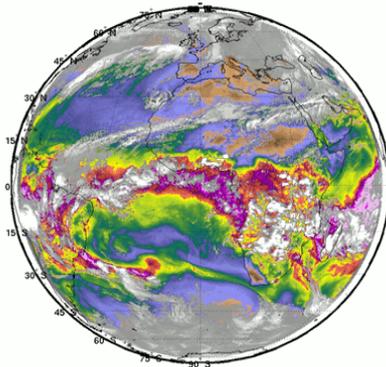
Baseline Product Examples



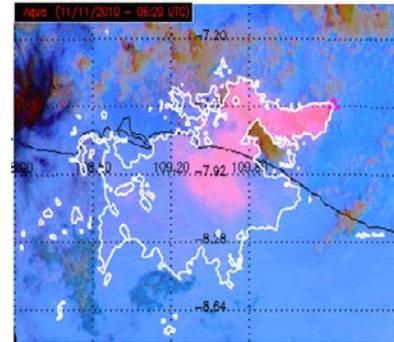
Cloud Height



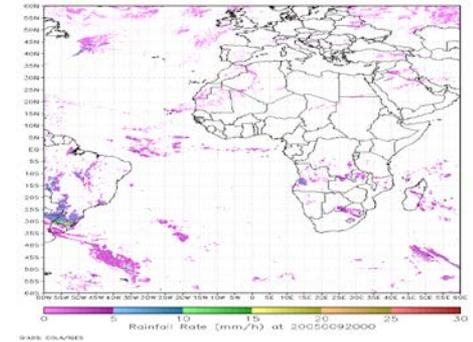
TPW



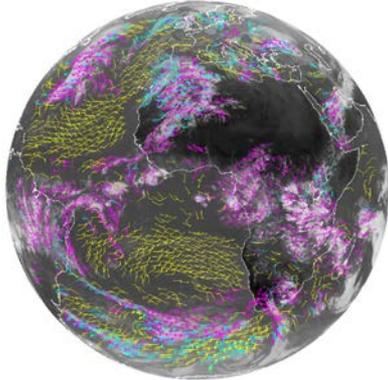
Volcanic Ash



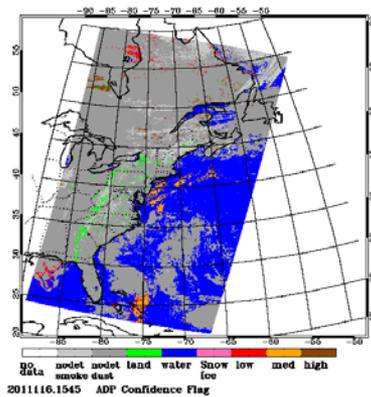
Rainfall Rate



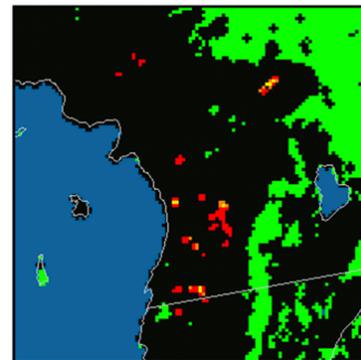
Winds



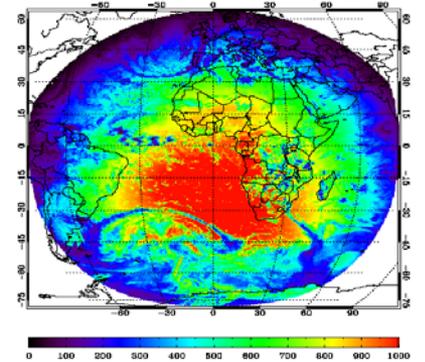
Aerosol Detection



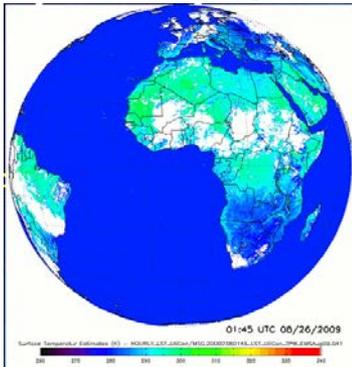
Fire Detection



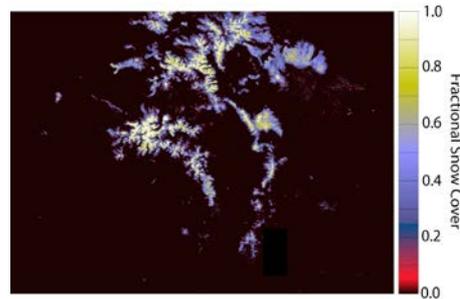
Shortwave Radiation (SFC)



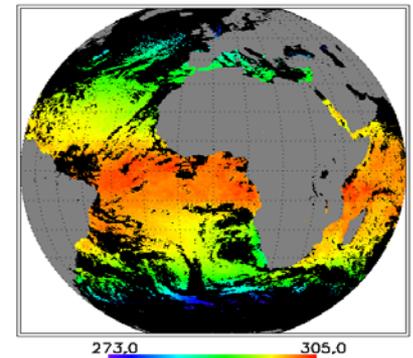
Land Surface Temperature



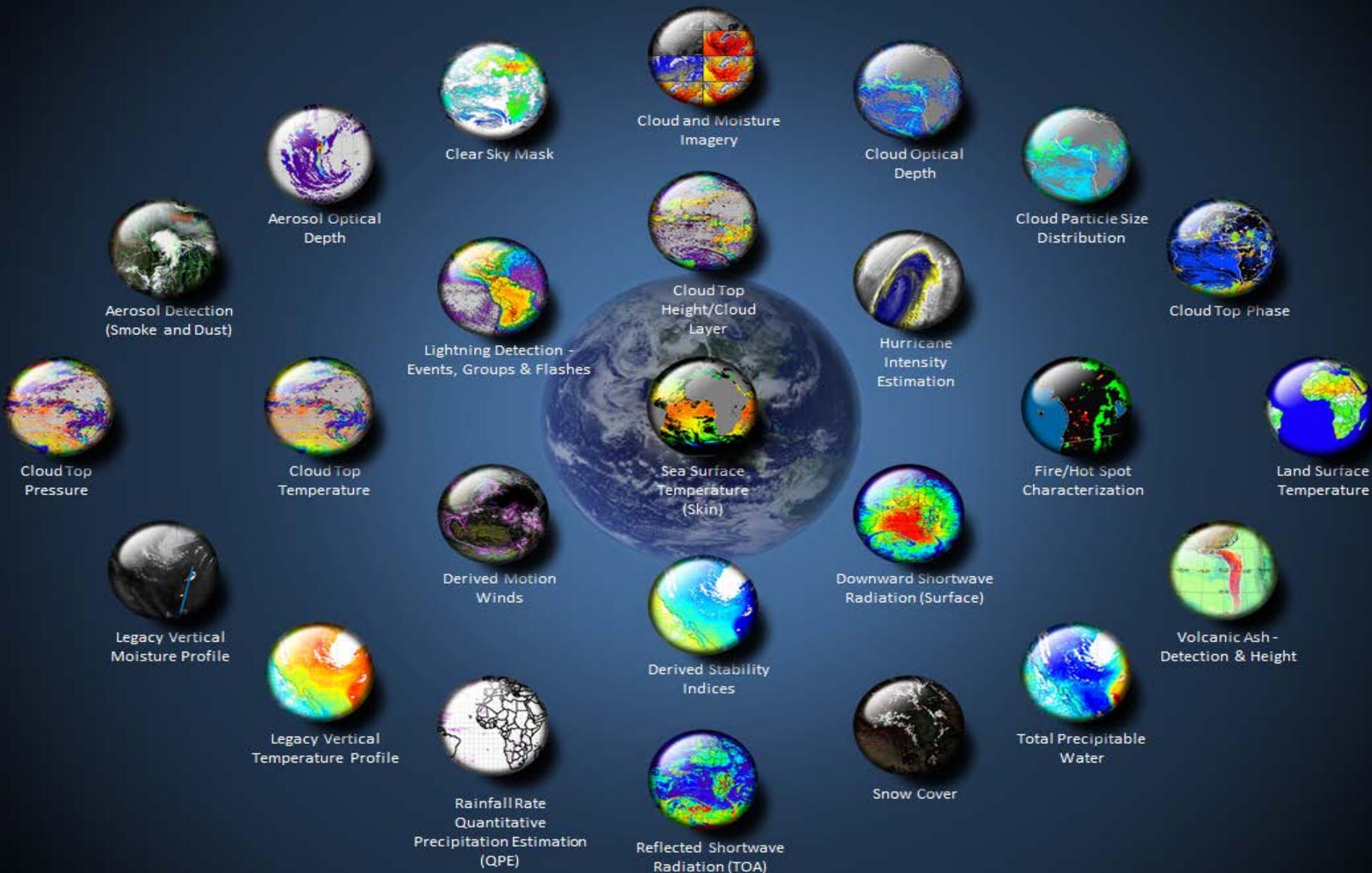
Snow Cover



SST



GOES-R Baseline Products



<http://www.goes-r.gov/products/baseline.html>



GOES-R Program's Commitment to Cal/Val

- Ensure instrument calibration requirements are met
- Perform independent testing of critical system components that affect data integrity
- Reduce risks associated with possible operational failure of on-board calibration systems
- Prepare NOAA satellite scientists and engineers for monitoring, analyzing and maintaining GOES-R series instrument calibration and **L1b** (*calibrated & navigated instrument data*) and **Level-2** (*environmental parameters*) product integrity after launch
- Support product validation to determine the degree to which GOES-R science data meets user needs
- User readiness

This foundation enhances understanding of data quality, and encourages “Day-1” readiness and long-term user confidence.



Validation

What it is and its importance...



Validation:

The process of determining that the deliverable item satisfies its intended use in its intended environment.

- ***GOES-R Program Acronym and Glossary***

The process of assessing, by independent means, the quality of the data products derived from the system outputs. [For example, assessing a derived L2 product against similar Reference/"Ground Truth" observations obtained from some other observing system (ground-based, satellite, NWP).]

- ***Committee on Earth Observation Satellites***

Validation provides user confidence that GOES-R data can be used for their intended purpose (weather forecasting, numerical weather prediction, or other applications)



Level-2 Product Validation

Objectives...



- ***Characterize the performance of the*** GOES-R Level-2 products
- Provide the GOES-R user community with operationally viable, validated, and useful data products for their applications and missions
- Provide investigations into any product issues that impact a customer's ability to fulfill their missions and provide effective solutions



GOES-R Program Calibration and Product Validation Strategy

Effective Date: 06-19-2009
Expiration Date: 06-19-2014
Responsible Organization: GOES-R/417

P417-RCALVAL-0192
Version: 1.0



Geostationary Operational Environmental Satellite (GOES)

Calibration and Product Validation Strategy

June 19, 2009



U.S. Department of Commerce (DOC)
National Oceanic and Atmospheric Administration (NOAA)

Describes:

- Scope of effort
- Organizational elements and working groups
- Activities, and roles and responsibilities, for each mission phase
- Resources
- Schedules



GOES-R Cal/Val Collaborators

Collaborator	Main Responsibilities	Cal	L1b Prod Val	L2+ Prod Val
Flight Project	Oversee SC/Instr. Design, Fabr., Integ., and Test	✓	✓	
SC/Instr Vendors	SC/Instr. Design, Fabr., Integ., and Test	✓	✓	
Ground Segment (GS) Project	Oversee GS Design, Fabr., Integ., and Test	✓	✓	✓
GS Vendor	GS Design, Fabr., Integ., and Test	✓	✓	✓
Mission Ops Support Team	Gov't SC/Instr/GS Test	✓	✓	✓
Data Ops Support Team	Gov't GS Test	✓	✓	✓
Cal Coordination Team (CCT)	PSE Coordination Support to GOES-R Instr. Cal & L1b Val	✓	✓	
Cal Working Group (CWG)	PSE Technical Support to GOES-R Instr. Cal & L1b Val	✓	✓	
Algorithm Working Group (AWG)	L2 Product Dev and V&V, and post-launch L2 product Validation (<u>science</u>)		✓	✓
NESDIS Office of Satellite and Product Operations (OSPO)	Ops Support to Cal/Val	✓	✓	✓



Prelaunch Activities...



Level-2 Product Validation (1/2)

Pre-Launch Strategies and Activities...



- **Continue generation and use of proxy data**
- **Continue validation and characterization of L2 product performance**
 - Through pre-launch Level-2 product demonstrations and validation studies
 - *Using available proxy data* and reference/"ground truth" measurements
 - Outlier studies (identify stressing cases, algorithm improvements)
 - Pursue more complete validation datasets (identify gaps; field campaigns)
- **Continue development/enhancements to baseline algorithms**
- **Development of product cal/val tools needed for**
 - Routine product monitoring
 - "Deep-dive" assessments and analysis of products

Strategies that enable the execution of GOES-R Level-2 product validation activities from pre-launch through the post-launch phases of the GOES-R Program.



Level-2 Product Validation (2/2)

Pre-Launch Strategies and Activities...



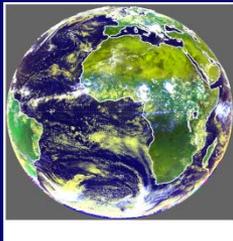
- **Development and use of an end-to-end capability and tools to assess the impacts of various instrument artifacts on the performance of Level-2 products**
 - Highlights the impacts of instrument calibration on Level-2 product performance
- **Build the necessary collaborations**
 - User community (*GOES-R Proving Ground and AWG Programs*)
 - Operational data providers (*NESDIS operations*)
 - Research community (*GOES-R Risk Reduction Program*)

Strategies that enable the execution of GOES-R Level-2 product validation activities from pre-launch through the post-launch phases of the GOES-R Program.

“Real” PROXY Data Sources

“Simulated” Proxy Data Sources

Meteosat/
SEVIRI



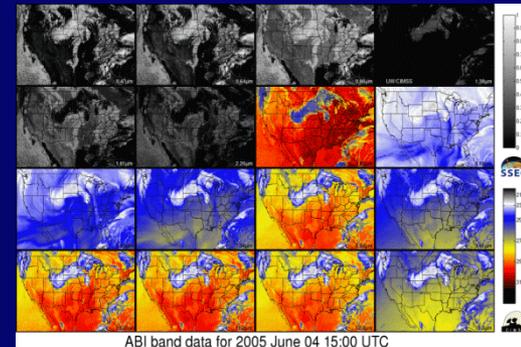
Current GOES



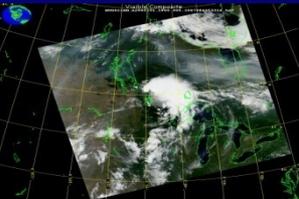
Future
Himawari-8



(FD, CONUS, Meso)



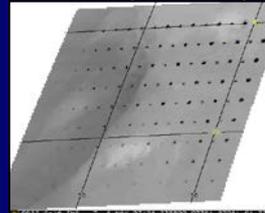
MODIS



TRMM/LIS

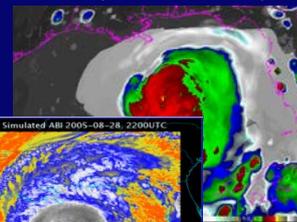


3.9um (for fires)

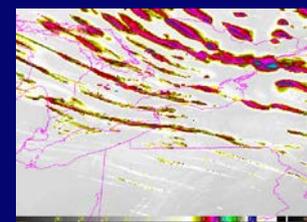


Case Studies

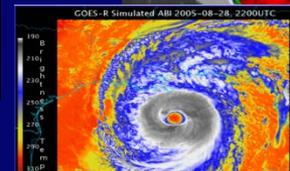
10.35um (Hurricane Lili)



10.35um (Lake Effect Snow)



11.2 um (Hurricane Katrina)

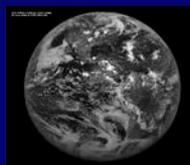
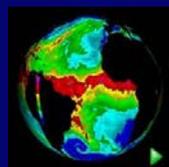
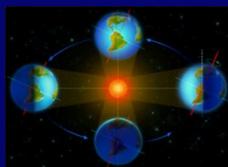


Additional sources of ABI proxy data: Suomi NPP VIIRS and Himawari AHI
GOES-14 SRSO experiment during Aug-Oct 2012 out-of-storage tests

The AWG teams continue to use available proxy data for their algorithm refinement, case study analyses, and product validation efforts...

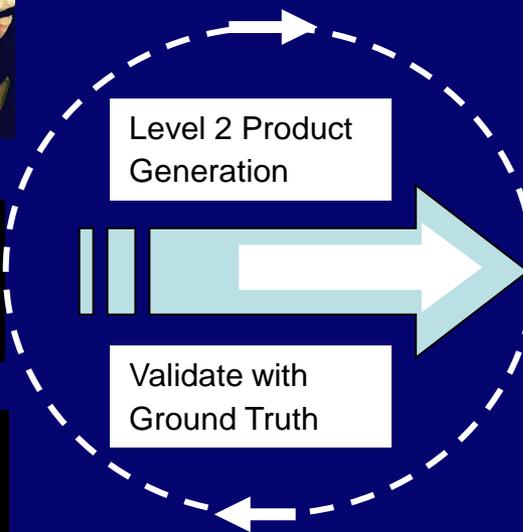
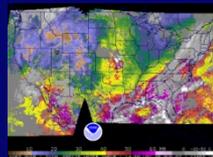
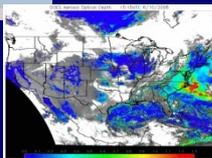
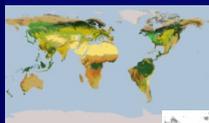


Assessing and Characterizing Algorithm Performance



Seasonal conditions represented

Wide variety of atmospheric and surface conditions are represented



- ✓ Pursue more complete validation
- ✓ Better estimates of product performance
- ✓ Increased confidence that on-orbit product performance will meet specs
- ✓ Increased confidence that user needs are met

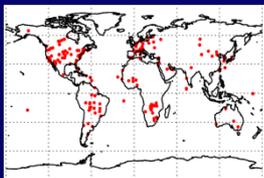
AWG teams continue to use proxy data to assess and characterize the performance of the baseline algorithms during this pre-launch phase of the GOES-R Program.



Reference/"Ground Truth" Data Sources



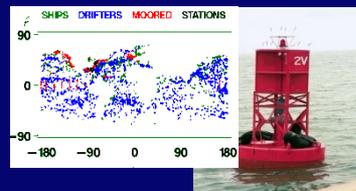
Aeronet Stations
Aerosol Optical Depth



CALIPSO, CLOUDSAT
Clouds, Icing



Bouys, Ships
SST



SURFRAD, ARM
LST, Radiation

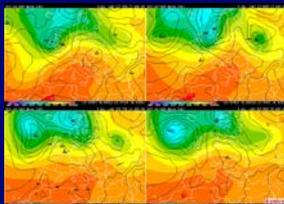


Radiosondes

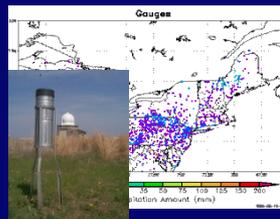
Winds, Temperature,
Moisture, Stability



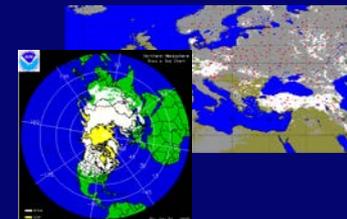
NWP Analyses
Winds, Temperature,
Moisture



Rain Guages
Precipitation



Sfc Snow Reports,
NESDIS IMS
Snow



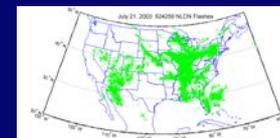
Ground-based Ozone
Ozone



Pilot Reports
Icing, Turbulence



National Lightning Detection
Network (NLDN)
Lightning

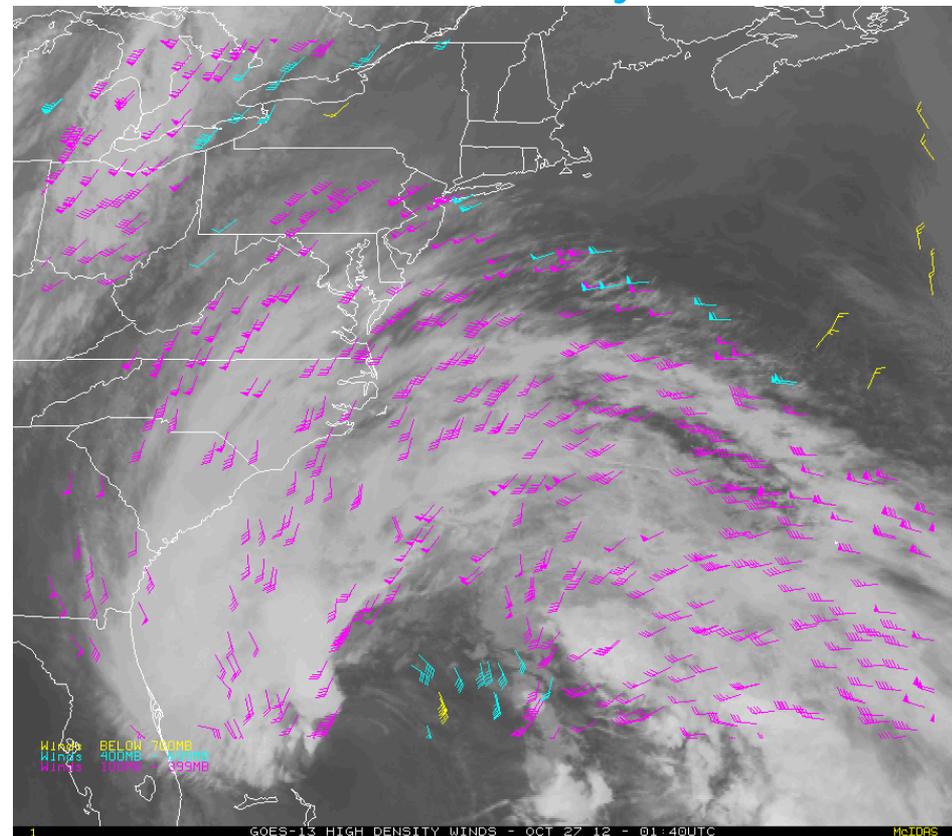


AWG Teams use a wide variety of Reference/"Ground Truth" datasets to assess and estimate Level-2 product algorithm performance.

GOES-13 Winds Over Hurricane Sandy Using GOES-R Clear-Sky Mask, Cloud and Derived Motion Winds (DMW) Algorithms

- Routine (hourly) experimental production of winds derived from GOES-13/15 imagery
- GOES-R cloud and wind algorithm software **modified slightly** to account for the current operational GOES imager instrument characteristics
- Derived winds are validated against available reference/"ground truth" observations (e.g., rawinsondes, CALIPSO)
- Derived winds are being archived locally for further analysis and use in future retrospective data assimilation studies

Hurricane Sandy

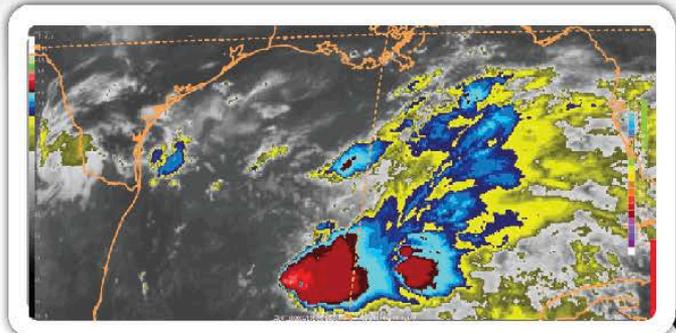


High-Level 100-400 mb Mid-Level 400-700 mb Low-Level >700 mb

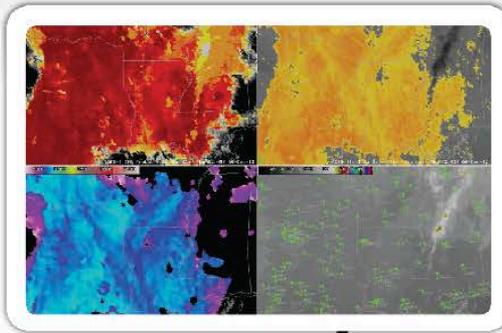
Cloud-drift winds derived from 15-minute GOES-13 11um imagery over Hurricane Sandy over the period October 27 (0140 UTC) through October 30 (1240 UTC) , 2012

Significance: Early demonstration of GOES-R algorithms using current operational GOES imagers.

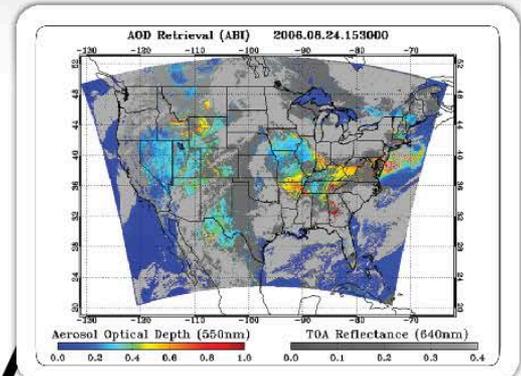
The GOES-R Proving Ground



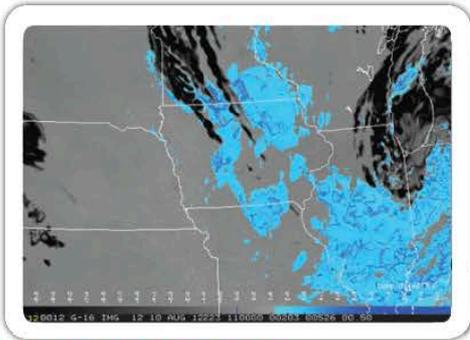
AWC – Kansas City, MO IR Imagery of Oceanic Storms



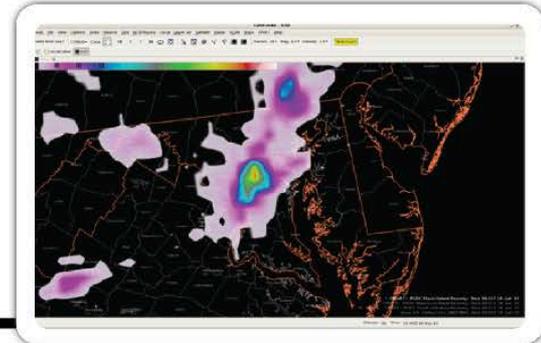
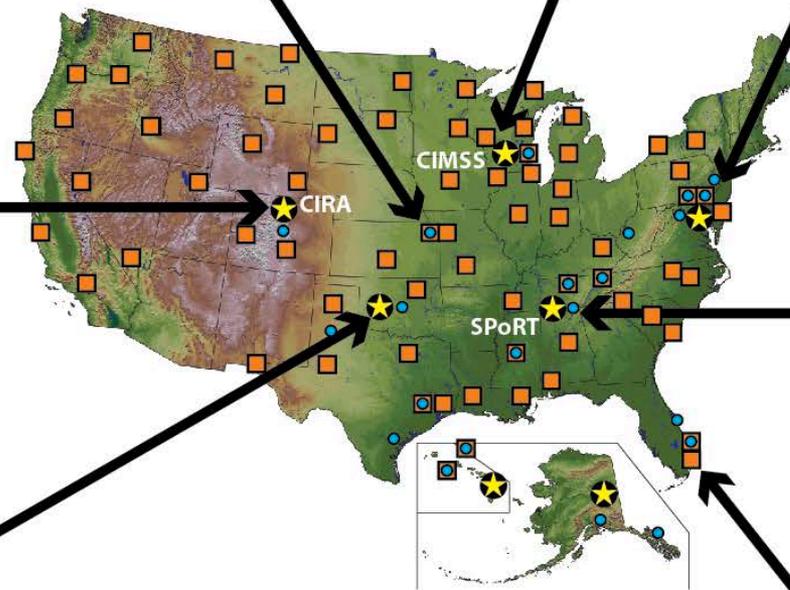
CIMSS/STAR – Madison, WI
Fog/Low Cloud Product



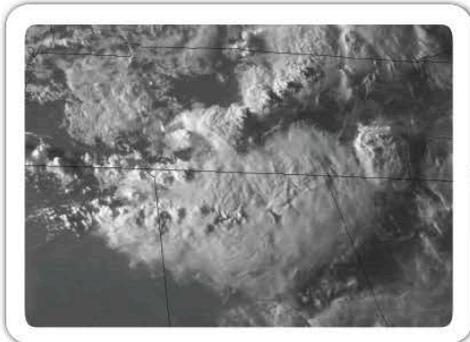
CICS/STAR – College Park, MD Aerosol Type Product



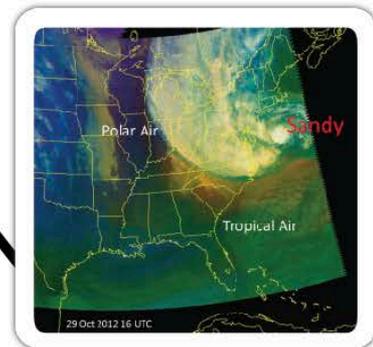
CIRA/STAR – Ft. Collins, CO
ABI Synthetic Low Cloud Enhancement Imagery



SPoRT/NASA – Huntsville, AL GLM Lightning Density



CIMMS/SPC – Norman, OK
Severe Storms 1-Min Visible Imagery of Overshooting Tops



NHC – Miami, FL
RGB Air Mass for Hurricane Sandy

- Evaluation Partner
- Product Development Partner
- ★ Cooperative Institute



AWG Cal/Val Tool Development

Two Categories of Validation Tools...



- **“Routine” Calibration/Validation Tools**
- **“Deep-dive” Calibration/Validation Tools**

“Routine” Validation Tools	“Deep Dive” Validation Tools
Provide means to routinely monitor product performance	Detailed analysis; problem resolution
Executed routinely and soon after product generation	Not executed in real-time. May need to wait for other datasets
Automated process	Run when more detailed analysis of product performance is needed
Run within NESDIS operations	Automated and/or Interactive components
	Run within NESDIS/STAR and its partners (CIs)



Routine Cal/Val Tools

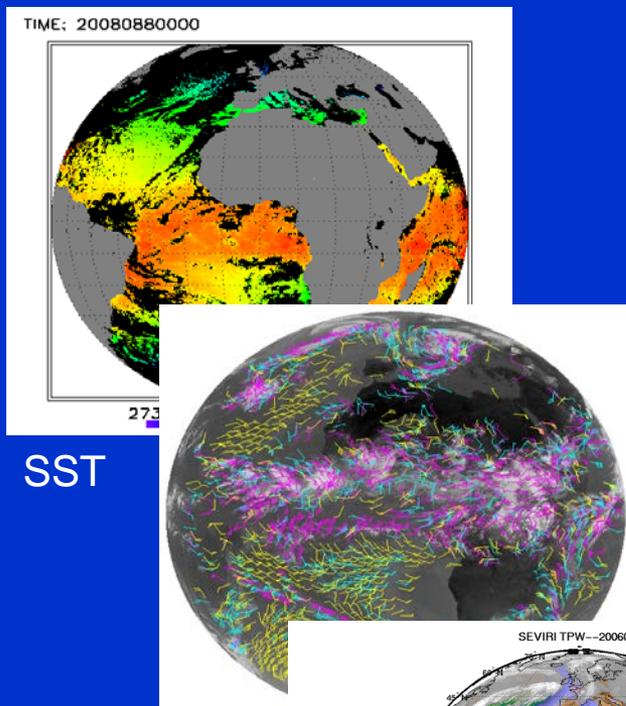


- Targeted for the routine and **automated monitoring** of operational Level-2 products
- Enable the **visualization** of products and/or reference (“truth”) data
- Perform the routine **collocation** of Level-2 products with their associated reference (“truth”) observations and the creation of comprehensive collocation databases
- Enable the **generation and visualization of comparison statistics** (retrieved quantity versus reference/“ground truth” observations)

Routine Cal/Val Tools

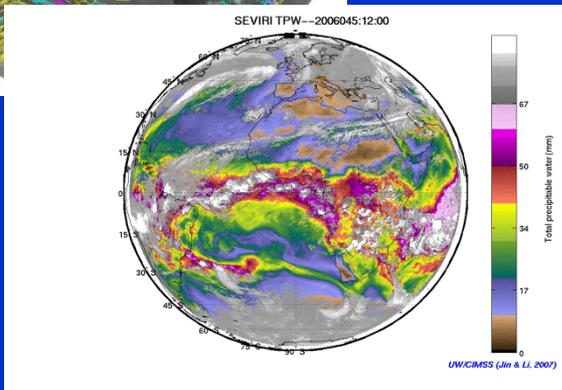
Some Example Output...

Product Visualization



SST

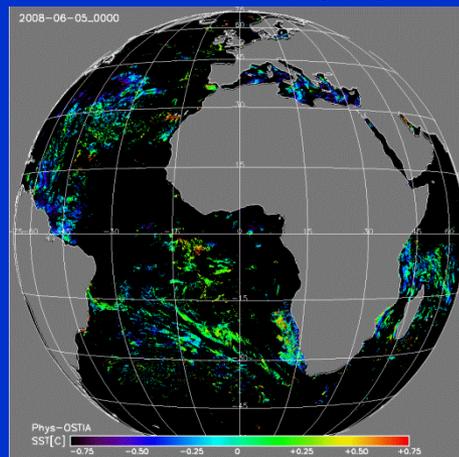
Winds



TPW

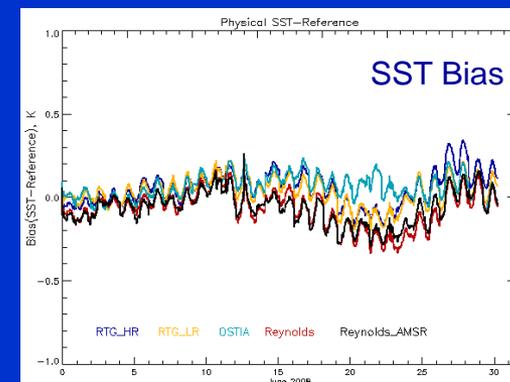
Retrieved Product – Reference/“Truth” Data

Horizontal Displays

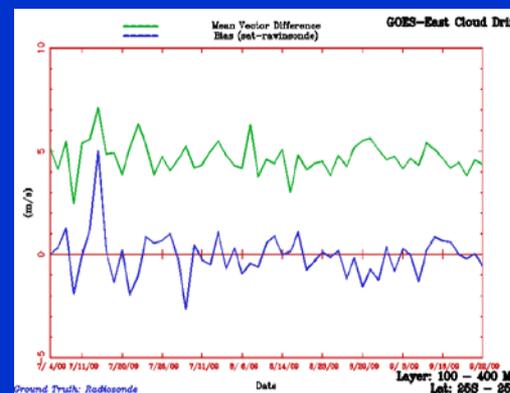


Retrieved SST – SST Analysis (UK Met Office)

Time Series of Comparison Statistics

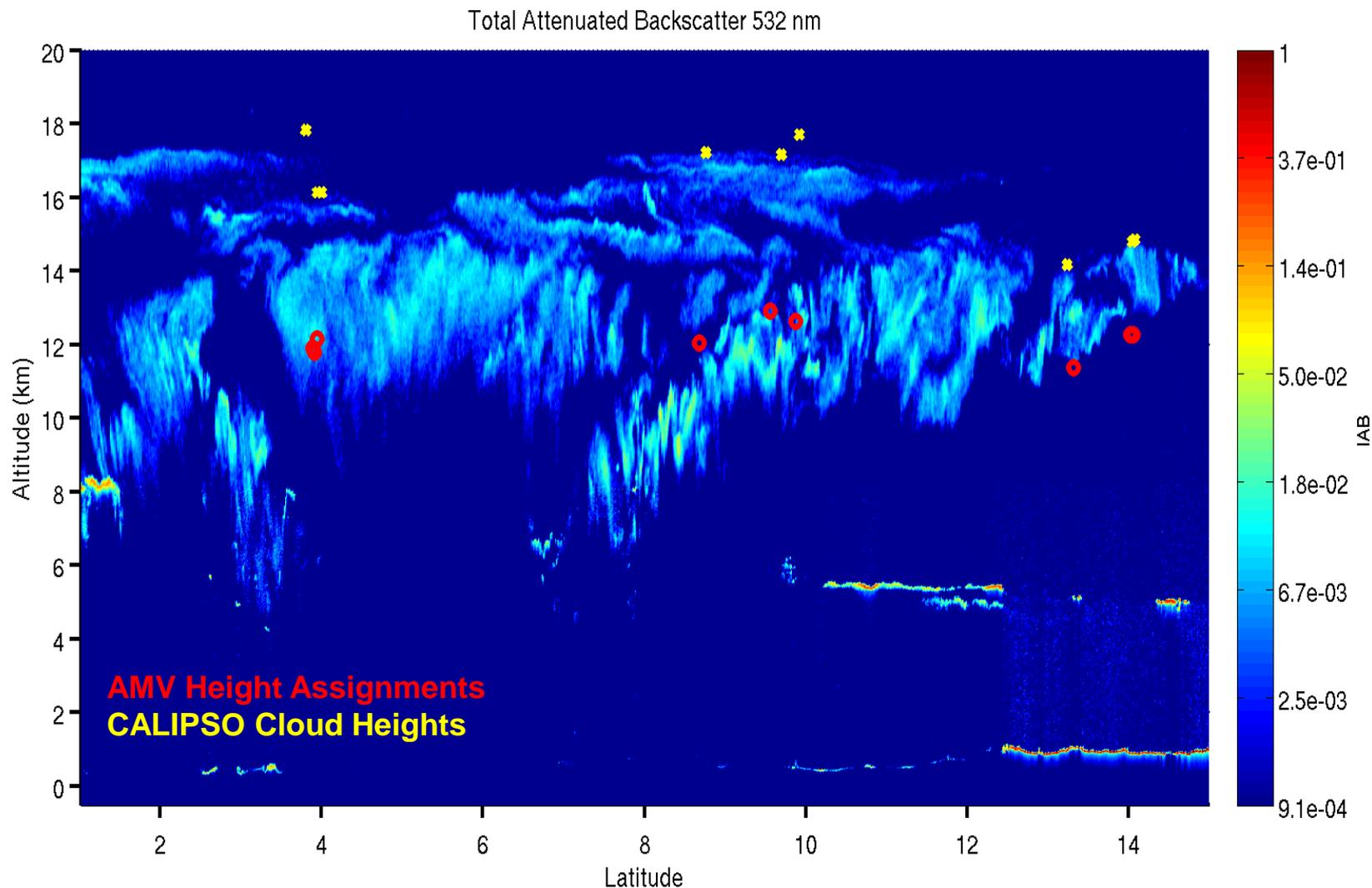


Retrieved SST – 5 different reference SST datasets



Time series of mean vector difference and speed bias metrics between high level (100-400 hPa) GOES-12 infrared cloud-drift IR winds and radiosondes

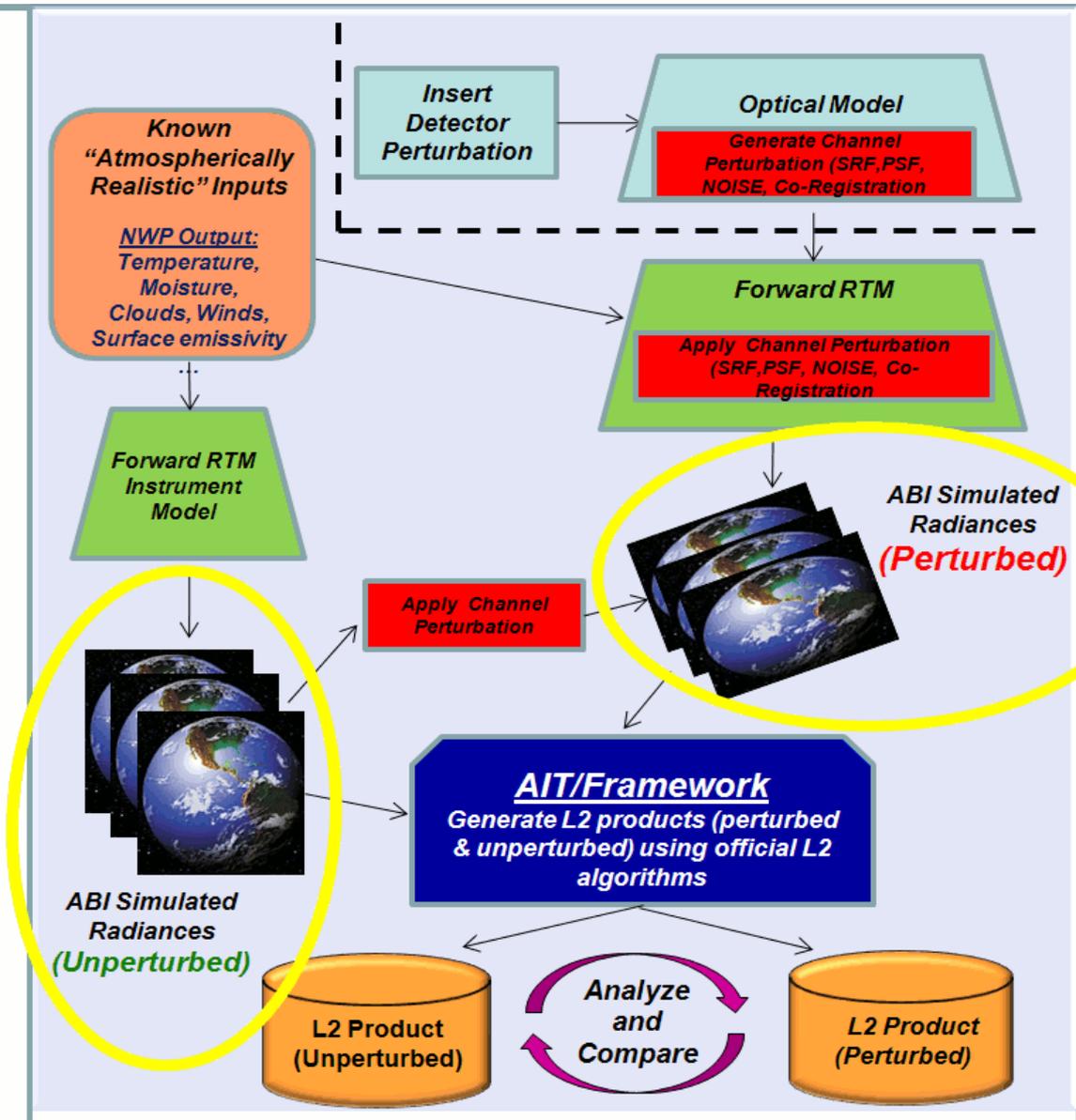
Example Deep Dive Validation: CALIPSO Cloud-Top Heights vs. AMV Height Assignments



GOES-R Analysis Facility for Instrument Impacts on Requirements (GRAFIIR)

➤ Collection of capabilities/tools that support the GOES-R Program's "Photons to Products Modeling Capabilities"

- **NWP modeling**
- **Radiative Transfer Model**
- **Instrument perturbation tools**
- **AWG L2 product algorithms**
- **GLANCE Tool: Statistical comparison tool to analyze and quantify impact of perturbations**





Planning for Post-launch Cal/Val Activities...



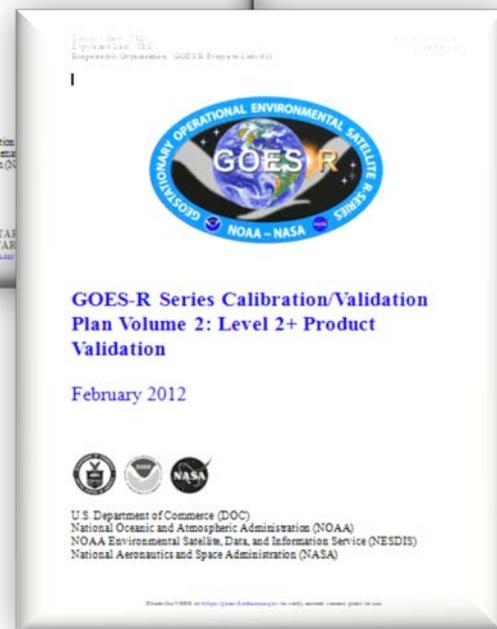
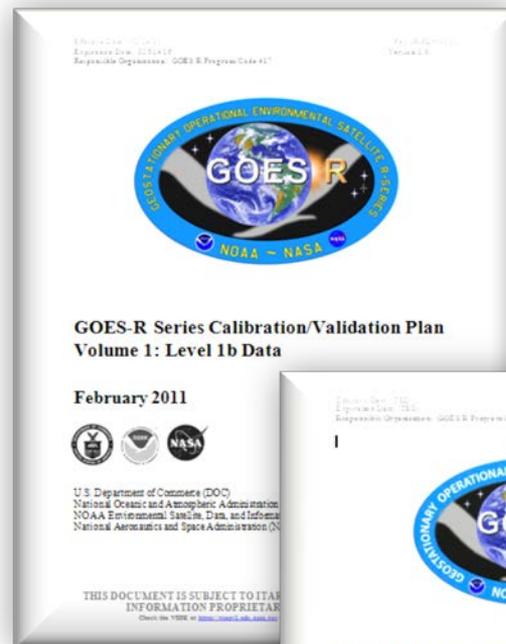
GOES-R Series Calibration and Validation Plans

- **GOES-R Series Cal/Val Plan Volume 1:
Level 1b Data**

- Describes the L1b product validation activities, methods, and processes including instrument under-flights

- **GOES-R Series Cal/Val Plan Volume 2:
Level 2+ Product Validation**

- Describes the post-launch Level-2 product validation methods, processes, and activities for each baseline product
 - During Post-Launch Product Testing (PLPT)
 - Longer term validation efforts of NOAA STAR on a per-product basis
 - Methodologies based on heritage of validation efforts for current GOES, POES, and MODIS missions



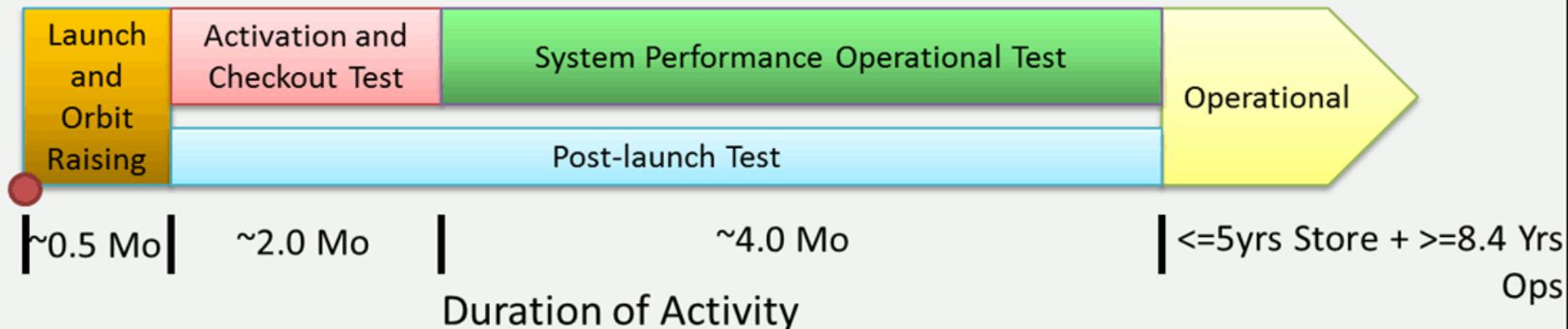
Cal/Val plans reflect GOES-R program plans for validating the products during pre-launch, post-launch, and throughout the mission.



GOES-R Series Post-launch Phases

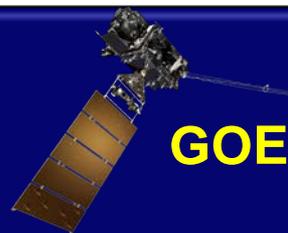
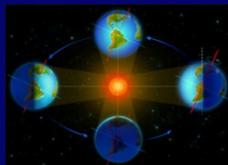
- **Post-launch checkout and test phase period currently planned for 6 months**
- **Activation and Checkout Test (ACT)**
 - Outgassing, data collection, spacecraft bus testing, communication testing, etc
- **System Performance Operational Test (SPOT)**
 - Bulk of time spent on instrument testing and characterization
 - End period (4-5 weeks) involves post-launch performance tests designed for Level-2 product validation ; Increasing data release to the user community and user interaction
- **Operational Phase**
 - Ongoing satellite ops, long term monitoring of spacecraft, instruments, and Level-2 products
 - Calibration updates, Level-2 product algorithm updates, new Level-2 products

GOES-R Series Post-launch Phases

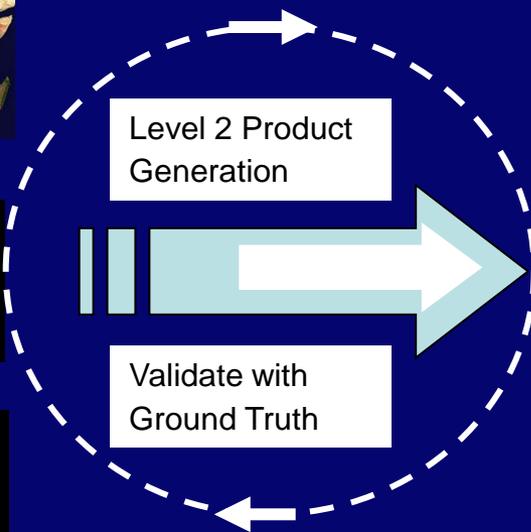




Assessing and Characterizing Algorithm Performance



GOES-R



Seasonal conditions represented

Wide variety of atmospheric and surface conditions are represented

- ✓ Measure on-orbit product performance
- ✓ Algorithm anomaly resolution and updates as needed
- ✓ Work closely with user community

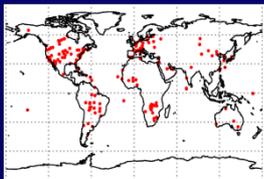
During the post-launch test phase, AWG product teams and the user community will assess and characterize the performance of the ABI baseline products.



Reference/"Ground Truth" Data Sources



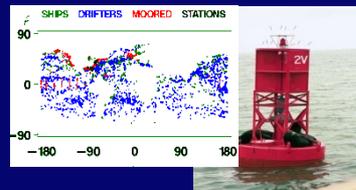
Aeronet Stations
Aerosol Optical Depth



CALIPSO, CLOUDSAT
Clouds, Icing



Bouys, Ships
SST



SURFRAD, ARM
LST, Radiation

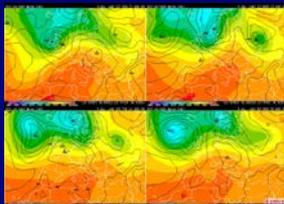


Radiosondes

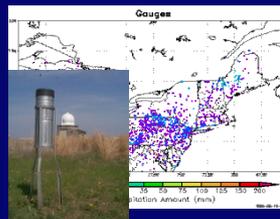
Winds, Temperature,
Moisture, Stability



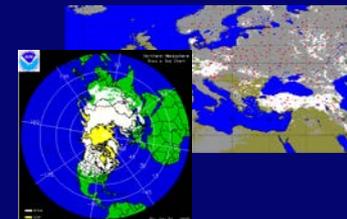
NWP Analyses
Winds, Temperature,
Moisture



Rain Guages
Precipitation



Sfc Snow Reports,
NESDIS IMS
Snow



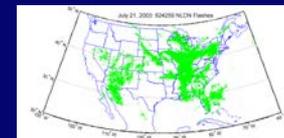
Ground-based Ozone
Ozone



Pilot Reports
Icing, Turbulence



National Lightning Detection
Network (NLDN)
Lightning



A wide variety of Reference/"Ground Truth" datasets will be used. Many of them will be the same ones the AWG used to develop the algorithms.



Summary



- The GOES-R Program is committed to calibration/validation (Cal/Val)
- End goal is high quality data and products that meet specification, but more importantly, meet the needs of NOAA's user community
- Significant amount of pre-launch activity aimed at readying the entire GOES-R system (flight and ground components)
- Cal/val tools are being developed for GOES-R products for use in during the post-launch phase
- Users are being engaged in a variety of ways (via GOES-R Proving Ground, AWG, and GOES-Risk Reduction programs) to help ensure their readiness on Day-1

Backup Slides



GOES-R Future Capabilities Products



- GOES-R AWG has developed algorithms for these products
 - Most are new; a few heritage
 - Will not be implemented into the Ground System on Day-1
- Opportunity to refine some of the products to address evolving user needs
- Effort to **prioritize**
 - Expanded advisory and decision making role for NWS to select which of these would best support forecast/warning operations
 - Identify *synergies* with polar products (NPP/JPSS)
 - Consider more *integrated* approaches and decision aid tools

Advanced Baseline Imager

Absorbed Shortwave Radiation: Surface	Probability of Rainfall
Aerosol Particle Size	Rainfall Potential
Aircraft Icing Threat	Sea and Lake Ice: Age
Cloud Ice Water Path	Sea and Lake Ice: Concentration
Cloud Layers/Heights	Sea and Lake Ice: Motion
Cloud Liquid Water	Snow Depth (Over Plains)
Cloud Type	SO₂ Detection
Convective Initiation	Surface Albedo
Currents	Surface Emissivity
Currents: Offshore	Tropopause Folding Turbulence Prediction
Downward Longwave Radiation: Surface	Upward Longwave Radiation: Surface
Enhanced "V"/Overshooting Top Detection	Upward Longwave Radiation: TOA
Flood/Standing Water	Vegetation Fraction: Green
Ice Cover	Vegetation Index
Low Cloud and Fog	Visibility
Ozone Total	

NWS High Priority Products desired for High Impact Weather Forecasts and Warnings



Calibration/Validation Phases



Launch

Pre-Launch

Post-Launch

Pre-launch Cal/Val

Early Orbit Check-out

Intensive Cal/Val

Long Term Monitoring & Operations

Sensor characterization - Radiometric calibration - Geolocation/navigation	Post-Launch Tests (PLT) and engineering tests (compliance)	Established sensor stability	QC/QA processes in place
Proxy data generation	Calibration Processing; Analysis of L1b products	Sensor characterization - Radiometric calibration - Geolocation/navigation	Continuous assessment & monitoring, trend analysis of product quality
Algorithm assessment and verification	Quick look analysis of L2 products; comparisons to NWP model/analyses	Finalize L2 algorithm tuning and testing; Establish L2 product stability	Algorithm improvements
Determination of validation strategies, including identification and acquisition of "ground-truth"/reference datasets	Work to establish sensor stability; Work to establish L1b and L2 product stability; L1b and L2 algorithm testing and tuning	L1b/L2 product validation processes in place; L1b and L2 product validations	Full and continuous data release to the user community
Cal/Val tool development	Establish routine validation processes	Increasing data release to the user community	Cal/Val tool improvements
Development of L1b & L2 Cal/Val Plans	Data released to users, but data is understood to be non-operational	Cal/Val tool improvements	Data Archival
	Data Archival	Data Archival	

Timeline

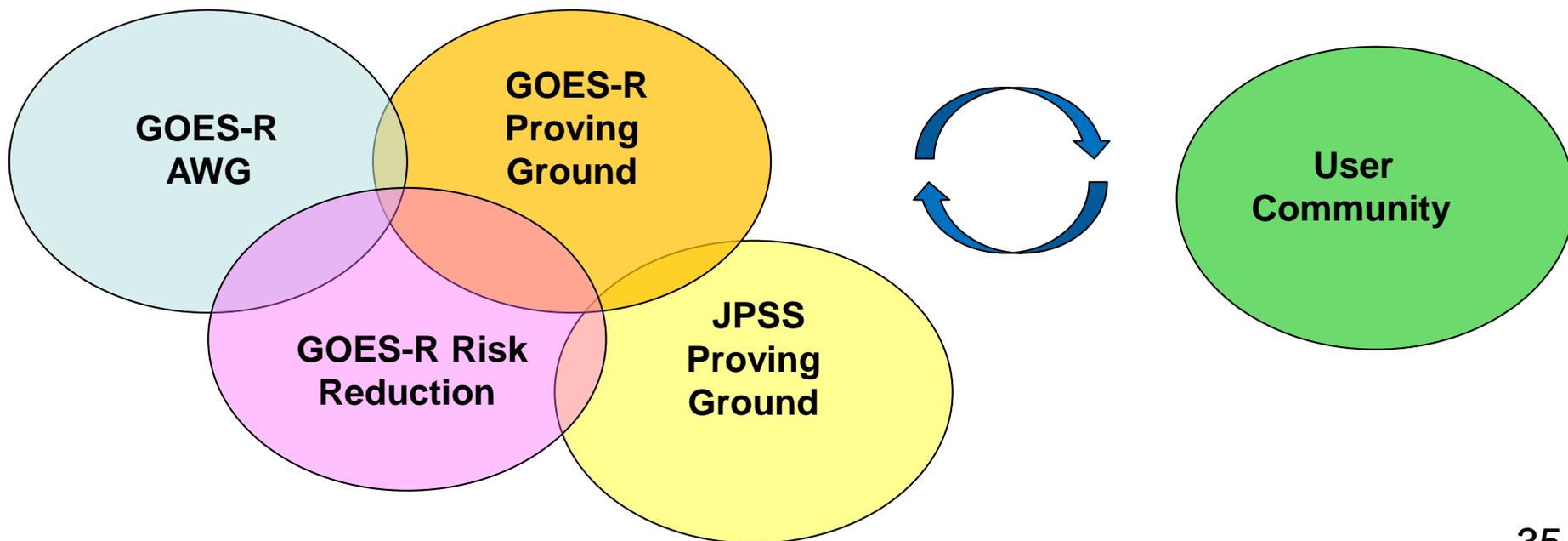
~6 months



Looking Ahead *Opportunities...*



- **Future Capabilities Product Algorithms**
 - Further develop/improve a number of these algorithms and/or their application to meet existing and evolving user needs.
- **New products** (Fused products, data fusion, decision aids)
- **Coordinated activities** between the GOES-R Program Office, AWG, GOES-R3, GOES-R Proving Ground, JCSDA, JPSS, and users will be critical for meeting these evolving needs





The GOES-R Proving Ground

- Collaborative effort between the GOES-R Program Office, selected NOAA Cooperative Institutes, NWS forecast offices, NCEP National Centers, NASA SPoRT, JCSDA, and NOAA Testbeds
- Responsible for user readiness testing of GOES-R baseline products and future capabilities prior to launch
- Where proxy and simulated GOES-R products are tested, evaluated, and integrated into operations before the GOES-R launch
 - Satellite Champions at NWS National Centers
 - Develop training for users
 - Prepare for display within AWIPS/AWIPS-II/N-AWIPS
 - Initial focus on High Impact Weather and warning related products requested by NWS
- A key element of GOES-R User Readiness (Risk Mitigation)
- Proving Ground activities are having an impact **NOW!**





GLANCE Tool

Example output...



msg land surface temperature Variable Comparison

report produced with glance, version 0.2.6.25
comparison generated Thu Mar 31 18:28:07 2011 by user graemem on cracklysec.wisc.edu

file A:

path: /data/graemem/sounding_verification_20110331/data/geocatL2.Meteosat-8.2006230.000000_033011.hdf
md5sum for file A: 1f8c873343313b2d3533935c6b1249b4
last modified: Thu Mar 31 13:41:53 2011

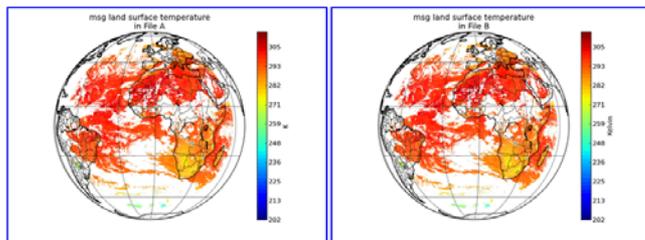
file B:

path: /data/graemem/sounding_verification_20110331/data/MSG8_SEVIRI_2006230_0000_00_AWG_SOUNDINGS_032411.nc
md5sum for file B: 47bb489e2c08cb5510eb57c0bbf807c
last modified: Thu Mar 31 13:44:39 2011

A configuration file was used to control the production report.
Please see [this copy of the configuration file](#) for details.

latitude in A: imager_prof_retr_msg_Lat_reduced
latitude in B: Latitude
longitude in A: imager_prof_retr_msg_Lon_reduced
longitude in B: Longitude
longitude/latitude comparison epsilon: 0.0001

Original Data



Comparison Information

variable name in A: imager_prof_retr_msg_Lst
variable name in B: LST
epsilon value: None
"missing" data value in A: -999.0
"missing" data value in B: -999.0
units in A: K
units in B: Kelvin

Statistical Summary

Finite Data Statistics

a Finite Data Statistics
a Finite Data Statistics
a Finite Data Statistics
b Finite Data Statistics
b Finite Data Statistics
common Finite Data Statistics
common Finite Data Statistics
finite_in_only_one Finite Data Statistics
finite_in_only_one Finite Data Statistics

General Statistics

a Missing Value Statistics
b Missing Value Statistics
epsilon
epsilon_percent
max_a
max_b
min_a
min_b
num_data_points
shape
spatially_invalid_pts_ignored_in_a
spatially_invalid_pts_ignored_in_b

Missing Value Statistics

a Missing Value Statistics
a Missing Value Statistics
b Missing Value Statistics
b Missing Value Statistics
common Missing Value Statistics
common Missing Value Statistics

NaN Statistics

a NaN Statistics
a NaN Statistics
b NaN Statistics
b NaN Statistics
common NaN Statistics
common NaN Statistics

Numerical Comparison Statistics

correlation
diff_outside_epsilon
diff_outside_epsilon_fraction
max_diff
mean_diff
median_diff
mismatch_points_count
mismatch_points_fraction
perfect_match_count
perfect_match_fraction
r-squared correlation
rms_diff
std_diff

